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Dr. Jennifer Mattei and research assistant Christine DePierro tag crabs at Milford Point.



The Horseshoe Crab Conundrum: Can we Harvest and Conserve?

Jennifer H. Mattei & Mark A. Beekey

Most everyone reading this article should thank a horseshoe crab for their good health!

--Not many people think of horseshoe crabs (*Limulus polyphemus*) while at the doctor's office but they should! These remarkable 'living fossils' have unique blood cells (amebocytes) that are used to test human vaccines for bacterial contamination. In the 1950's, scientists at the Marine Biological Laboratory in Woods Hole, Massachusetts, not only discovered amebocytes but also found that they had special properties. If the amebocytes came into contact with bacteria, they would instantly coagulate around the bacteria and attack it. The Woods Hole scientists took this unique property of horseshoe crabs and developed a test for bacterial contamination using a horseshoe crab blood derivative called Limulus Amebocyte Lysate (LAL).

Today, federal law requires any medical device or product that will be inserted or injected into a human body be tested for bacterial contamination using Limulus Amebocyte Lysate (LAL). For example, each year pharmaceutical companies produce new Flu vaccines and test them for bacterial contamination with LAL. If a batch is found to be contaminated, then it is thrown out. This test ensures that those people receiving their annual flu vaccine do not become ill from a tainted vaccine batch.



©M. Beekey

This vial contains a freeze dried sample of *Limulus* Amebocyte Lysate (LAL) which is extracted and purified from horseshoe crab blood and sold around the world to test vaccines for bacterial contamination.

Even the family dog is protected by horseshoe crab blood, as the LAL test is also required for veterinary practices, to avoid contaminated rabies vaccines. Remarkably, NASA has taken horseshoe crab blood into outer space to help keep our astronauts healthy. If an astronaut comes down with a sore throat they can swab their throat and use their LAL test kit to see if it is a bacterial or viral infection. A positive test result informs the astronaut to take antibiotics. Further research is currently being conducted on the unique properties of horseshoe crab blood. There exists a real possibility of finding anti-cancer products that could benefit human health in the future.

Economic importance

Horseshoe crabs are worth millions of dollars and not just for their exceptionally useful blood products. Commercial fishermen that harvest eel (*Anguilla rostrata*) and whelk (*Busycon spp.*), which are mainly exported and sold in Asian markets, utilize millions of horseshoe crabs annually for bait. In fact, no other bait works as well for attracting eel and whelks to the traps. The fishermen in Delaware have been working with the U.S. Fish and Wildlife Service to help reduce the harvest. Instead of using a whole horseshoe crab, the bait is quartered and placed in a special mesh bag allowing one horseshoe crab to be utilized where four or more were used in the past. Researchers at the University of Delaware and the Delaware Biological Institute discovered that one attractant for eel and whelk was actually a protein present in horseshoe crab eggs. These researchers are now trying to develop an artificial protein that can be manufactured and placed in artificial bait with the hope of reducing the harvest of horseshoe crabs.

The ecological importance of horseshoe crabs in their natural habitat is undervalued.

Horseshoe crabs are now considered to be a 'key-stone' species because of the tremendous numbers of shorebirds, fish, and invertebrates that rely on their eggs for nutrition. Millions of horseshoe crabs spawn on the shores of New Jersey, Delaware, Maryland, and Virginia usually starting in mid-May through June. At least

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Green eggs in sand:

Horseshoe crab eggs can be found at about 2.3 to 4 inches (6-10 cm) below the surface of the sand. These eggs are from Sandy Point, New Haven Harbor.



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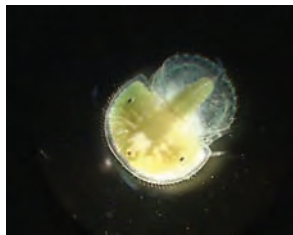
eleven species of shorebirds time their northward migration to this spawning event.

Increasing levels of attention has been paid to one particular shorebird, the red knot (*Calidris canutus*), because as the horseshoe crab population began to decline so did the numbers of red knots. Red knots feed on horseshoe crab eggs to fuel their journey to Canada where the birds breed. If the red knots do not acquire enough eggs during their two-week stay in Delaware Bay they may not survive their journey to the Arctic.

Horseshoe crabs are intricately linked to many species within the continental shelf. *Limulus* eggs and larvae are undoubtedly food sources for many species of fish and invertebrates that are a part of the benthic intertidal community. In addition, many species call the horseshoe crab shell their home! The horseshoe crab shell is habitat for more than 20 species of encrusting or sessile marine organisms and is host to a unique flatworm parasite (*Bdelloura candida*). This *Limulus* 'leech' exists commensally on the outside of the shell; however it may weaken its host by laying hundreds of eggs in its gills. Adult horseshoe crabs have very few predators although some have been found in the stomachs of large sharks and loggerhead sea turtles; its unique body shape and hard shell prevent most predators from eating the adults.

The American Horseshoe Crab

Limulus polyphemus is an extraordinary animal only found along the coast of North America from southern Maine to Florida with a few populations along the Yucatan Peninsula of Mexico. With 10 eyes distributed



One-week old *Limulus* larva

© M. Beckey

More than 16,000 horseshoe crabs in Long Island Sound are tagged with a small yellow cinch tag. This year new disc tags provided by the U.S. Fish and wildlife service are being used. Please report the unique tag number and location if you spot one. Call the number on the tag or e-mail info@projectlimulus.org

across its back, belly, and telson (tail), and teeth-like spines on its knees with its mouth located between its legs, one wonders what on earth this creature could be related too? Its closest living relatives are spiders and scorpions, not crabs.

We accompanied a group of students from Columbus School (Bridgeport) to Milford Point so that they could learn about these strange creatures.

One boy yelled out with authority, 'Watch out the tail will sting you!'

Another student shouted, 'That tail is a sword, it will cut you!'

The students soon learned that the horseshoe crabs' telson is completely harmless. *Limulus* is one of the most benign creatures in the ocean. It harbors no malice towards the people it shares the beach with in the summer. It cannot even pinch very hard. The horseshoe crab needs its telson to survive. It is used as a lever to help right itself when flipped upside down by waves on the beach. To help make the point, a conservation campaign in Delaware Bay called, "Just Flip 'em" asks beach goers to right upside down horseshoe crabs on the beach to help them get back to the sea after they spawn.

So what is the horseshoe crab conundrum?

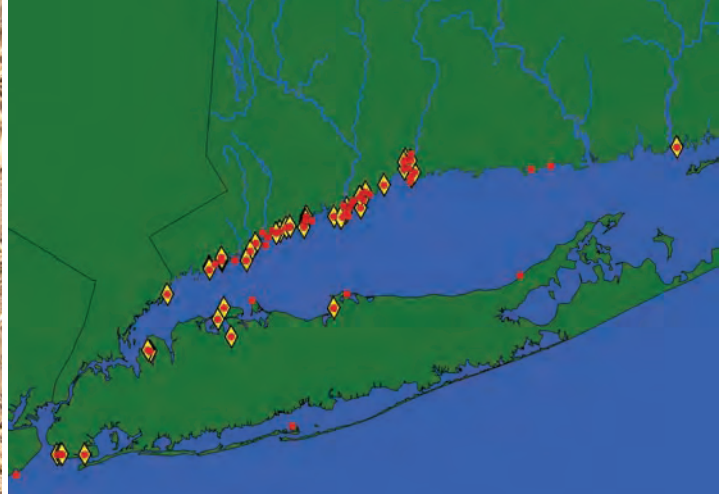
Horseshoe crab populations are *seemingly* in decline throughout much of their range. This decline may have gone unnoticed except for the concurrent decline of specific shorebird populations. 'Seemingly' is not a very precise word for a scientist to use, but we still know very

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Sonar tags allow researchers to follow horseshoe crabs around Long Island Sound. Each tag produces a unique pattern of “pings” that allow Project *Limulus* researchers to identify individual animals.



Map of Long Island Sound depicting tagging sites (yellow points) and recapture locations (red dots). The yellow points on the map above represent our tagging sites through 2006.

little about how many there are or what they need to survive let alone how tightly linked others species are that rely on horseshoe crabs for their own survival. This is especially true for Long Island Sound. In fact, the only published study on horseshoe crab population ecology in Long Island Sound was conducted in 1957 in Cold Spring Harbor. Our conundrum is that if we don't understand the ecology of horseshoe crabs in Long Island Sound, then how can we effectively manage them in order to keep horseshoe crabs abundant, for all of their uses? If we can't guarantee their future survival, then what will happen to the shorebirds, fish, invertebrates and the millions of people that depend on them? The purpose of our now 6-year-old mark/recapture study is to understand more about the population ecology of the horseshoe crab and how it utilizes Long Island Sound for survival and reproduction.

Some of what we have learned so far

In Delaware Bay, where the horseshoe crab population densities are higher, clustered mating behaviors (i.e. polyandry) consisting of a female with two or more males were reported to be 44 percent when counted in 1993. On Connecticut beaches, polyandry was observed only 6 percent of the time. An abnormal behavior that has not been reported to occur in Delaware Bay was that on average, 30 percent of the females tagged on the beach were single. Also, about half of the males coming up on the beach were single. These observations lead us to believe that mating success is density dependent and as populations decline horseshoe crabs may have difficulty finding mates. Our research lends support for the

CTDEP's decision to close certain spawning beaches to harvest. However, monitoring of nest densities needs to take place in order to see if any positive effect on population density will result from these closures.

The majority of our tagging takes place along the western Connecticut coast of Long Island Sound. Most of the tagging along the north shore of Long Island was conducted by trawl aboard the schooner 'SoundWaters'. As of 2007, we have tagged over 16,000 crabs. Thanks to the efforts of many volunteers, we have recaptured more than 1,300 crabs. Most of the recaptures (red dots) are in the western portion of LIS but we have had some long distance travelers—one crab traveled from Brooklyn, NY all the way to Rhode Island! What we have learned so far from these tagging efforts is male horseshoe crabs stay longer around the same beach during spawning season while females tend to move among beaches laying multiple clutches of eggs. However, between seasons, both males and females rarely return to the same beach to spawn. This lack of fidelity to specific spawning beaches supports the establishment of multiple no harvest zones to protect prime spawning areas for horseshoe crabs. We have also found that the majority of crabs tagged in LIS stay in LIS. We have observed little movement of tagged horseshoe crabs outside of the Sound.

Our findings support the notion of a closed population. We need to determine if the population is in decline or if it is recovering. This summer, with funding from Connecticut Sea Grant, we are exploring the ecology of species linked to the horseshoe crab spawning events in LIS. We will determine if shorebirds, fish,

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The majority of mating horseshoe crabs tagged in Long Island Sound occur in pairs, with the smaller male attached to the back of the female.

crabs, or other predators feed on *Limulus* eggs and larvae as well as continue our mark/recapture efforts. We are only able to do this with the help of citizens from Connecticut and New York. Therefore connected with our study is a community based research and science literacy campaign entitled 'Project *Limulus*'.

We need your help for Project *Limulus* to succeed!

Project *Limulus* is a long-term project that spans a large coastal area encompassing the Long Island Sound ecosystem. The project is a community based research effort that becomes more successful if more people volunteer to help. Students of all ages (from k-12 to senior citizens) may get involved with this study, all are welcome to participate. In order for our study of horseshoe crab abundance and distribution to be successful we need the help of every community member that lives near or likes to visit the beaches of LIS. Specifically, we need you to keep an eye out for horseshoe crabs with yellow plastic spaghetti tags or white discs (see pictures above) attached to their side. We need you to call or e-mail the unique number on each tag, what beach you found it on and if it was dead or alive. Investigations that bring scientists and students of all ages together result in a better understanding of the scientific process and appreciation of our natural resources. Obviously, not all research is amenable to community participation but some projects can benefit greatly by the data collected from young aspiring scientists, their teachers, and citizen scientists.

The data you collect greatly benefits university researchers, undergraduates and k-12 participants, but

more importantly your contribution can help inspire the next generation of scientists.

So what can you do?

You may participate in Project *Limulus* at three levels:

Beach Walkers: volunteers search for tagged horseshoe crabs that come up on the beaches and report the tag numbers found.

Beach Census Takers: volunteers will be trained to count male and female horseshoe crabs in a defined area (sometimes these counts are at night).

Beach Taggers: volunteers will be trained to tag and measure horseshoe crabs (both night and day tagging)

The spawning period usually occurs from the second week of May to the end of June. Participants may go out as little or as often as they like however, beach census takers will require at least four trips to the beach. We hold information and training sessions in May and June, and will do so again in 2009. Exact places and times will be announced shortly on our website:

<http://www.projectlimulus.org> (click on Training and Workshops). If you want more information or would like to volunteer, please send an e-mail to <info@projectlimulus.org>. Please include your name and contact information and we will be in touch!

There are many resources available for additional information including a brand new Nature video about horseshoe crabs and shorebirds in Delaware:

<http://www.pbs.org/wnet/nature/crash/>.

Here are several books:

The American Horseshoe Crab by Carl Schuster

Limulus in the Limelight: A Species 350 Million Years in the Making and in Peril? By John Tanacredi



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Excited young scientists participating in Project *Limulus* at Columbus School in Bridgeport, Connecticut.

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K. Hjort



Authors Jennifer Mattei and Mark Beekey look for horseshoe crabs during the Project *Limulus* monitoring.

Please also check out the following web sites to get an idea of what becoming a member of Project *Limulus* is like:

http://www.wfcr.org/field_notes/animals/070702_FN-horseshoe_crabs.mp3

<http://www.longislandsoundstudy.net/horseshoecrab>

The horseshoe crab is part of an ancient line of species that have survived morphologically unchanged through the 'Big Five' mass extinctions, including the 'mother' of all mass extinctions at the end of the Permian, where some 95 percent of all ocean dwelling species went extinct. It would be a shame to allow horseshoe crabs to disappear after 400 million years of evolution and survival because of our abuse of the Sound and its shorelines. The only way we can safely harvest this species and increase population size is by gaining an understanding of its population dynamics. Please help us solve the horseshoe crab conundrum by volunteering for any level of participation that you can.

Project *Limulus* has been supported by a grant from the Long Island Sound License Plate Program, managed by the Connecticut Department of Environmental Protection, Sacred Heart University and the NOAA Fisheries, Northeast Fisheries Science Center, Milford Lab. It also has had funding from the National Fish and Wildlife Foundation, Long Island Sound Study, Wildlife Trust, Unilever, and PSE&G. Other groups participating in this project include, The Maritime Aquarium, Connecticut Audubon, SoundWaters, The Nature Conservancy, Project Oceanology, National Audubon, The Sound School, Bridgeport Aquaculture

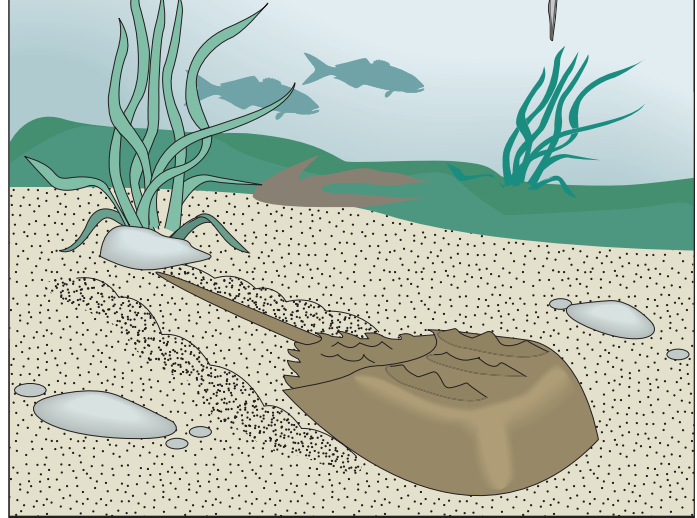
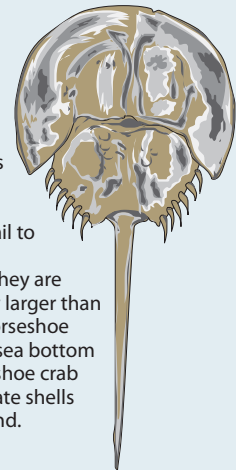
School, The New York Aquarium, The Brooklyn Children's Museum, New York City Urban Park Rangers, New York State Park Rangers Long Island Region, Columbus School and Warren Harding High School of Bridgeport, and the Yale Peabody Museum. Support from Connecticut Sea Grant will begin this summer. The results of the present study will be shared freely with participating education programs in an effort to increase public awareness of this species and Long Island Sound ecology. With the information we gather, a sound conservation program may be implemented in Connecticut and New York to prevent the over-harvesting and local extinction of the horseshoe crab.

About the Authors: Dr. Jennifer Mattei is an Associate Professor and Chair of the Department of Biology and Dr. Mark Beekey is an Assistant Professor of Biology from Sacred Heart University in Fairfield, Connecticut.

Sound facts

Older than the dinosaurs

The horseshoe crab really isn't a crab; it is more closely related to spiders. It has changed very little since 455 million years ago, during the Ordovician period of the Paleozoic Era. The horseshoe crab's five pairs of legs and its mouth are sheltered beneath its large, dome-shaped shell. Its long, spike-shaped tail isn't a weapon; it uses its tail to right itself if it gets tipped over. Its gills, underneath, are called "book gills" because they are arranged like pages in a book. Females grow larger than males, with a shell diameter of a foot. The horseshoe crab feeds by plowing through sand on the sea bottom to find worms and small shellfish. The horseshoe crab must shed its shell as it grows, and the delicate shells are often found on beaches around the Sound.



Source: Sierra Club Naturalist's Guide

Milton Moore/The Day